Exploring for volatiles in the regolith outside of the lunar polar regions

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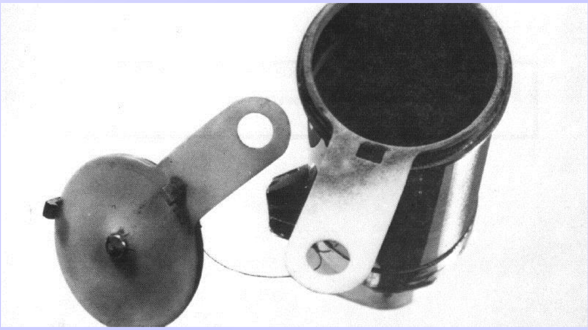
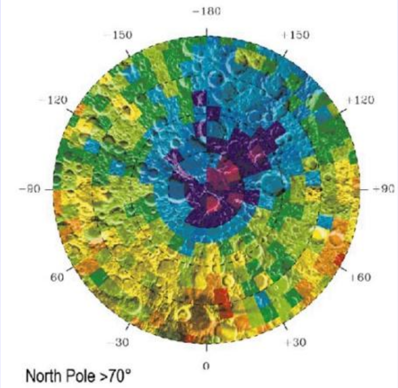
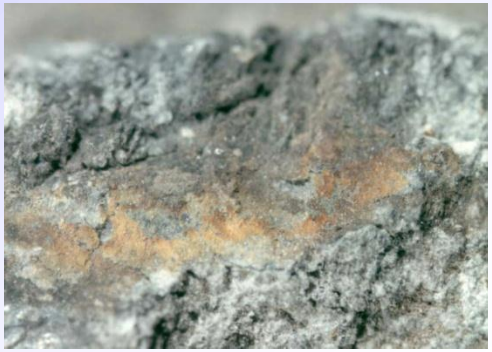
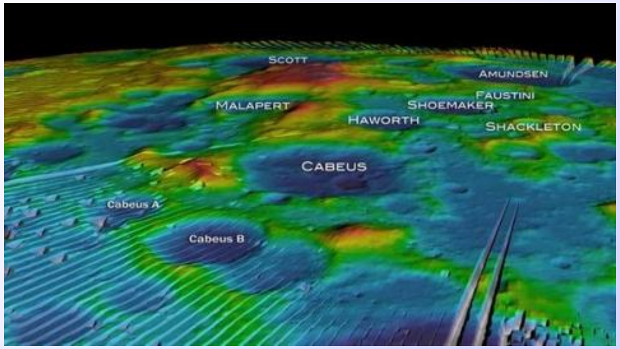


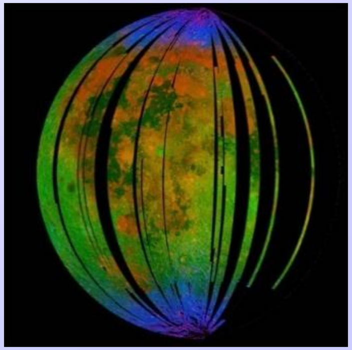




Revealing a New Moon
Role of Lunar Volatiles

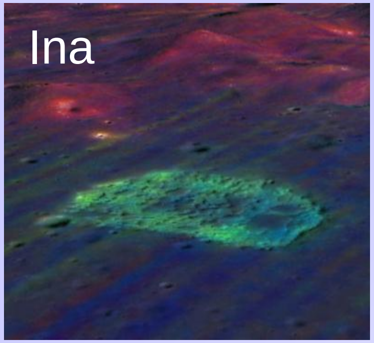


Clementine, Lunar Prospector, LRO, LCROSS: What is the nature of H species and other volatiles in polar regions?

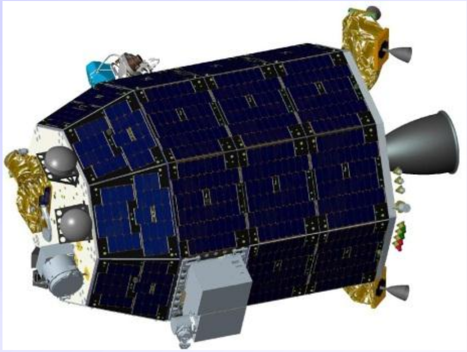


Chandrayaan-1 M³: What is the nature of H species outside the polar regions?

Studies of Apollo samples: What is the nature of H species and other volatiles in the lunar interior?



LRO and Chandrayaan-1 M³: What is the nature of volatile degasing at the lunar surface?



LADEE: How will future lunar exploration shape the moon's environment and how will the environment affect future explorers?

Understanding Lunar Volatiles

Examples from "Planetary Science in the Decade 2013-2022"

UNDERSTAND THE ORIGIN AND DIVERSITY OF TERRESTRIAL PLANETS.

- What are the volatile budgets in the interiors, surfaces and atmospheres of the inner planets? (page 114)

UNDERSTAND HOW THE EVOLUTION OF TERRESTRIAL PLANETS ENABLES AND LIMITS THE ORIGIN AND EVOLUTION OF LIFE.

- How are volatile elements and compounds distributed, transported, and sequestered in near-surface environments on the surfaces of the Moon and Mercury? (page 118)

- What are the chemical and isotopic compositions of H-rich deposits near the Moon's surface? (page 118)

- What are the mechanisms by which volatile species are lost from terrestrial planets , with and without atmospheres and with and without significant magnetic fields? (page 120)

Understanding Lunar Volatiles

Examples from "Moon Next Strategic Knowledge Gaps" initially identified by the Human Space Flight Architecture Team

Examples of Lunar SKG relevant to lunar volatiles

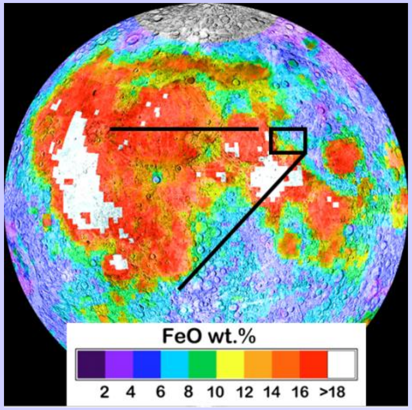
- ***Quality/quantity of water and volatiles in Lunar Regolith.***
- ***Resource processing.***
- Biological effects of lunar dust.
  - Measure reactivity of archived Apollo samples/lunar regolith simulant.
  - Measurements of the most pristine samples could yield the best data.

There are common SKG themes across destinations (Moon, NEA, Mars)

- The three R's for enabling human missions
  - Radiation
  - Regolith
  - Reliability
- Geotechnical properties (Moon, NEAs, Mars)
- ***Volatiles (i.e., for science, resources, and safety) (Moon, NEAs, Mars)***
- ***Sampling volatile reservoirs and curating these material.***
- Propulsion-induced ejecta (Moon, NEAs, Mars)
- ***In-Situ Resource Utilization (ISRU)/Prospecting (Moon, NEAs, Mars).***

Sampling the lunar volatile record

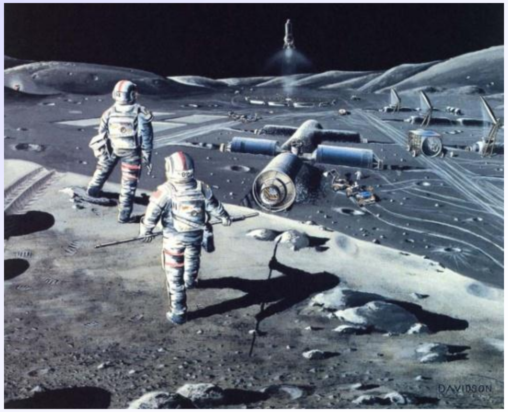
Important yet difficult



Samples provide ground truth for

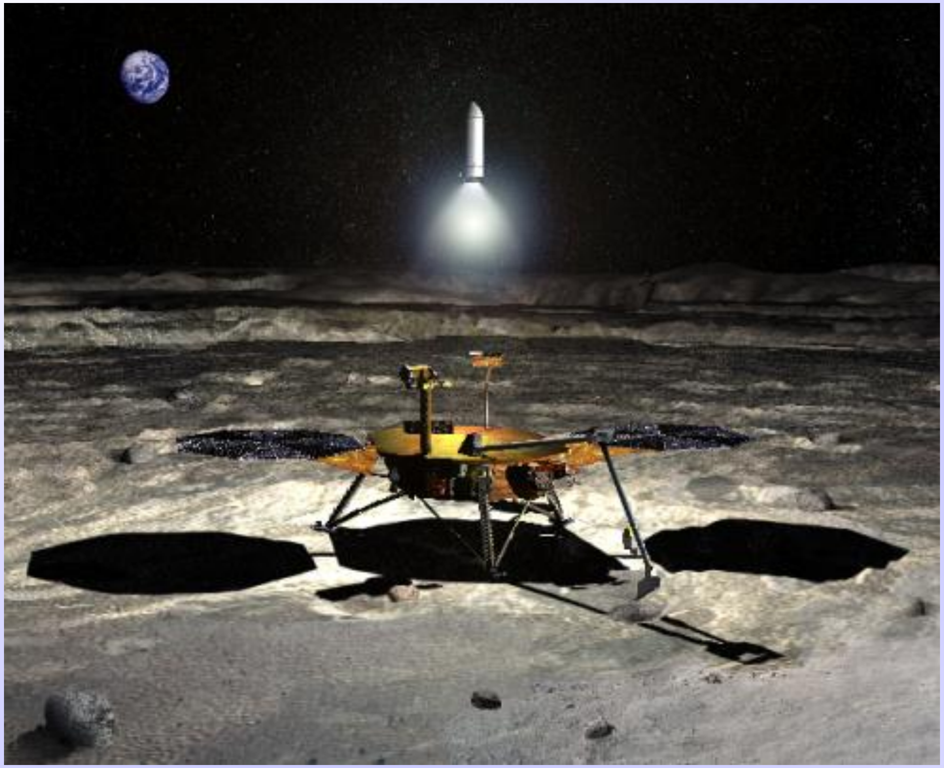
- interpreting remotely sensed data.
- providing details for lunar processes.
- identifying potential resources.

Apollo samples have provided insights into the behavior of volatiles on the Moon. How well is this volatile record preserved?



How can environmentally sensitive samples be better collected, processed, and preserved beyond approaches used during the Apollo Program?

Lunar missions to answer planetary science questions and fill strategic knowledge gaps



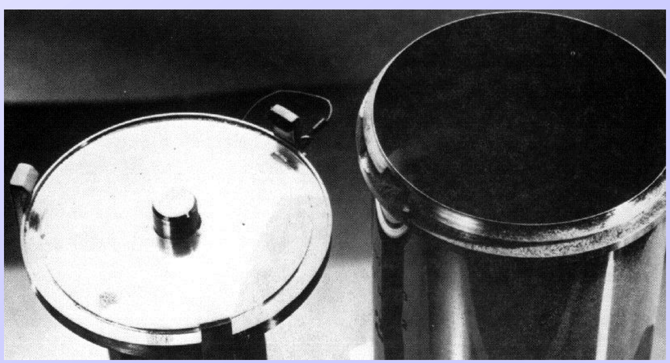
Precursor- or Discovery-style missions to explore for lunar volatiles in regolith.

Study of unopened Apollo samples.

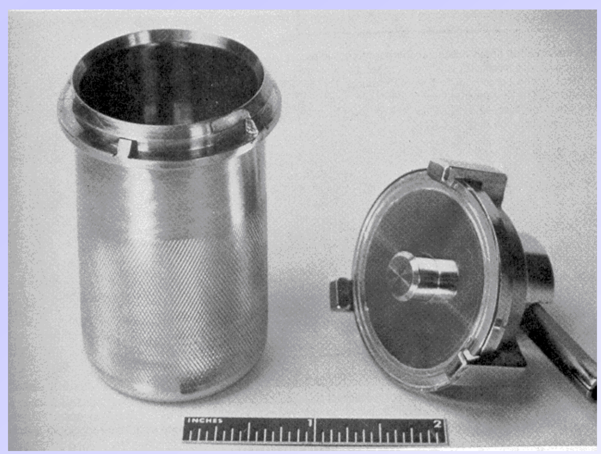
Examples of sample containers that were used during the Apollo Program

Apollo Lunar Sample Return Container (A-16)

J-mission sample bag which contains soil sample 74220 (1180 grams)



Special Environmental Sample Container and Core Vacuum Sample Container

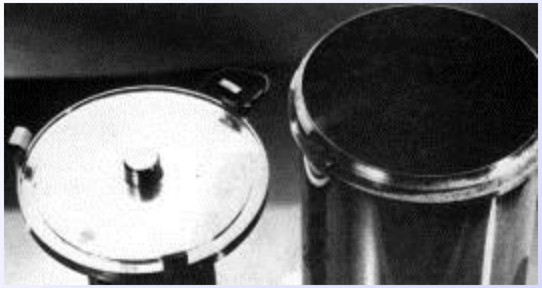


Gas Analysis Sample Container

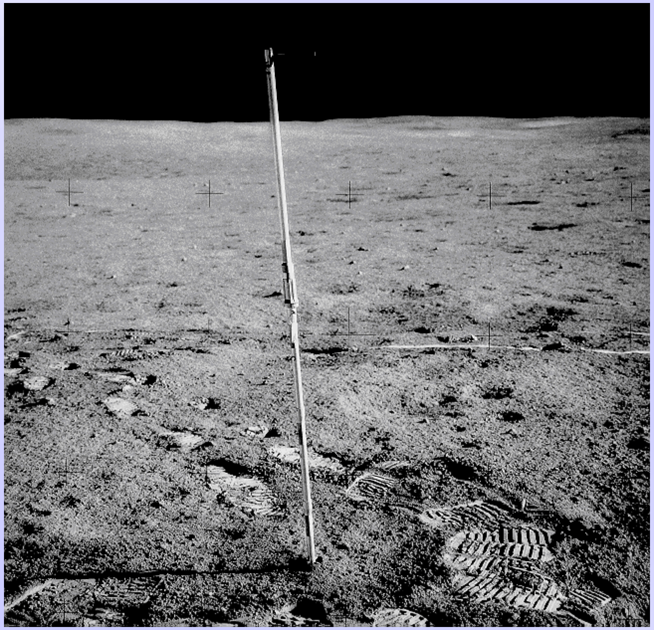
Fig. 90. Protective Padded Sample Bag (NASA photo S72-43790).

Protective Padded Sample Bag

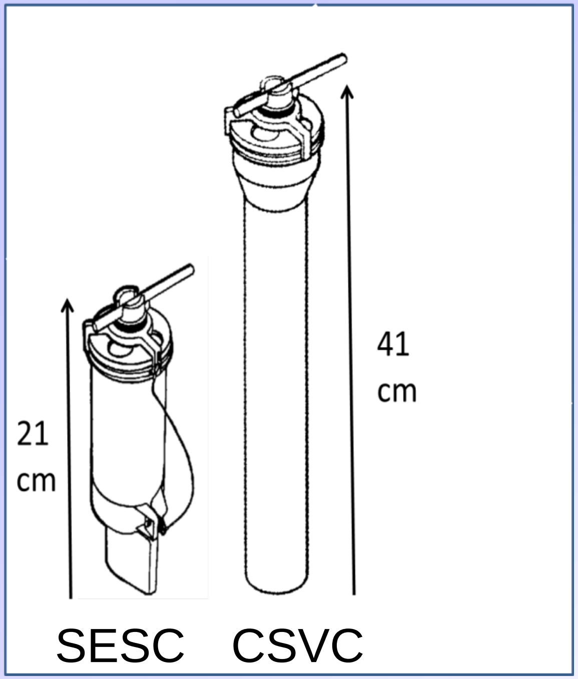
Unopened Apollo samples



15014
Special Environmental
Sample Container 333 g



73002 Drive tube 429 g
70012 Drive tube 434 g



69001 Core Sample
Vacuum Container 558 g
73001 Core Sample
Vacuum Container 809 g

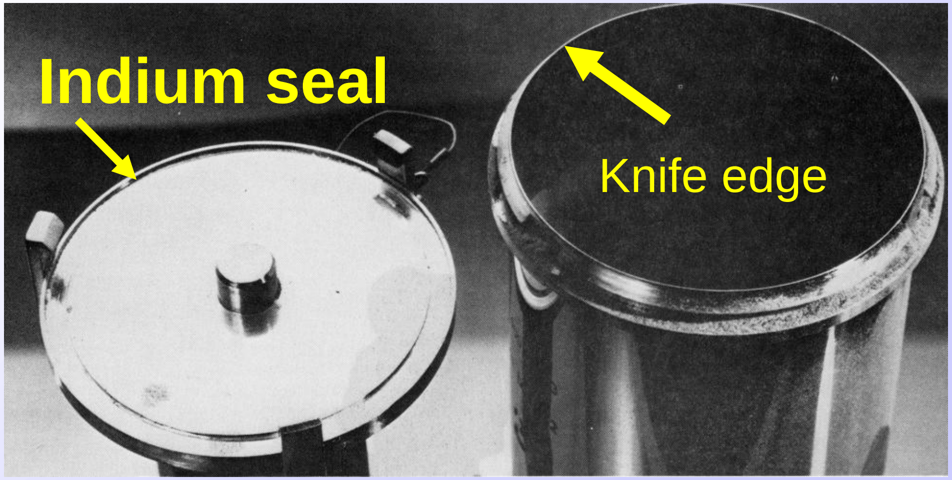
CSVC
Core Sample Vacuum Container

Weight
493 g

Length
41 cm

O. D.
6.1 cm

Seals on CSVC



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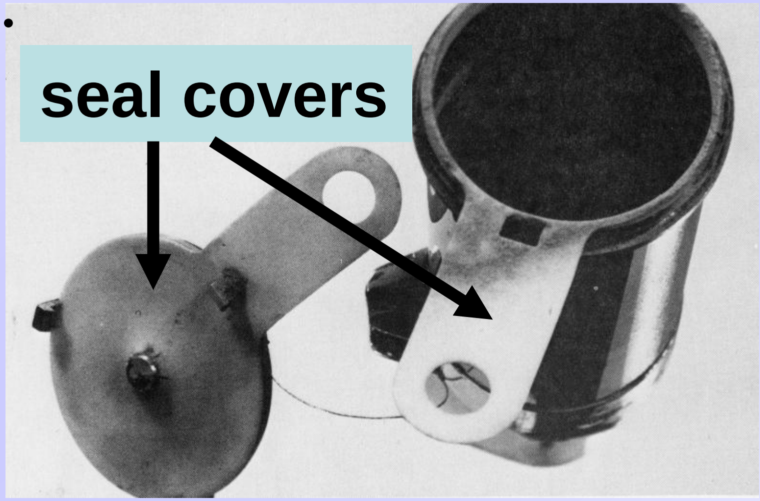
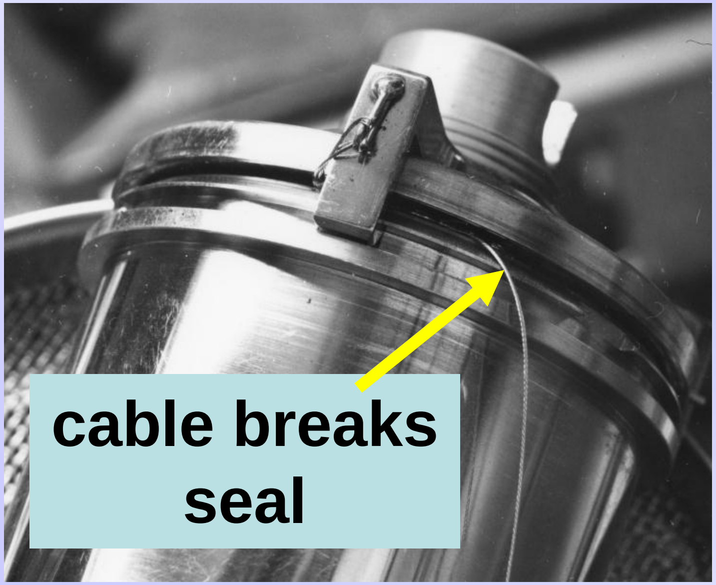
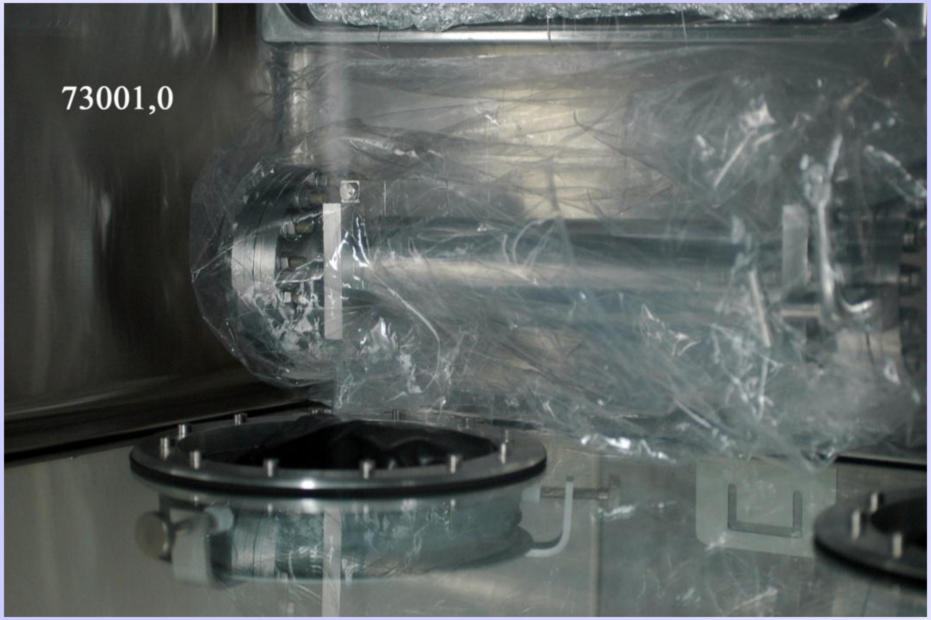
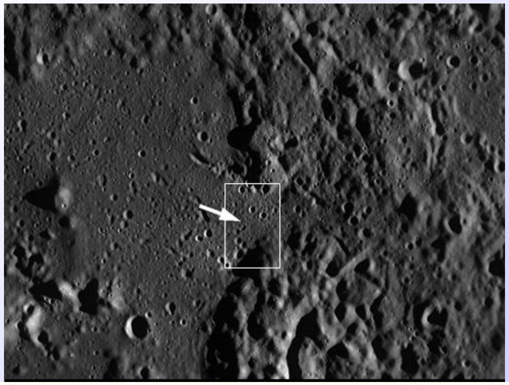


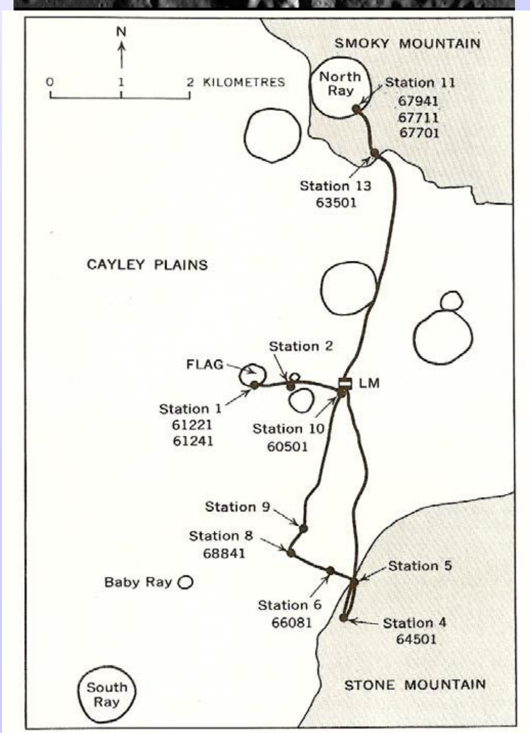


Current Status of CSVC



History of Unopened CSVC
69001 Core Sample Vacuum Container





- Single drive tube core collected at sta. 9 N. of S. Ray Crater, 2.5 km S. of LM
- Immediately placed in vacuum container (CSVC) on lunar surface
- Upon return to LRL placed in additional vacuum container
- Approx. 558 grams, depth 27.5± 2 cm intentionally not driven all the way in

Why Now?

Pressing planetary <u>science problems</u> tied to past, current, and future missions and recent sample observations.

- A “wet” or “dry” Moon?
- What and where are the volatile reservoirs on the Moon?
- How and when are water and other volatiles delivered to planetary bodies?
- What are the natural and contaminated abundances of C and organics in the lunar regolith?

Pressing problems tied to <u>human exploration</u>.

- Exploring potential resources.
- Processing and using lunar resources.
- Base-line for human impact on the lunar environment.

Substantial <u>improvement in analytical technology</u> since the mid-1970s that enables new measurements.

Tests collection, storage, and curation of volatile-bearing planetary materials that <u>feed forward to future missions</u>.

- What are the priority challenges and infrastructure-technology needs for NASA curation over the next decade?

Why a Consortium?

Many distinct measurements with many different instruments are required to be made on material from a single **Core Sample Vacuum Container.**

Long history of consortium studies of lunar material (VAPOR, Highlands Initiative) that illustrate success.

A single, coordinated processing, allocation, and analytical protocol is required for:

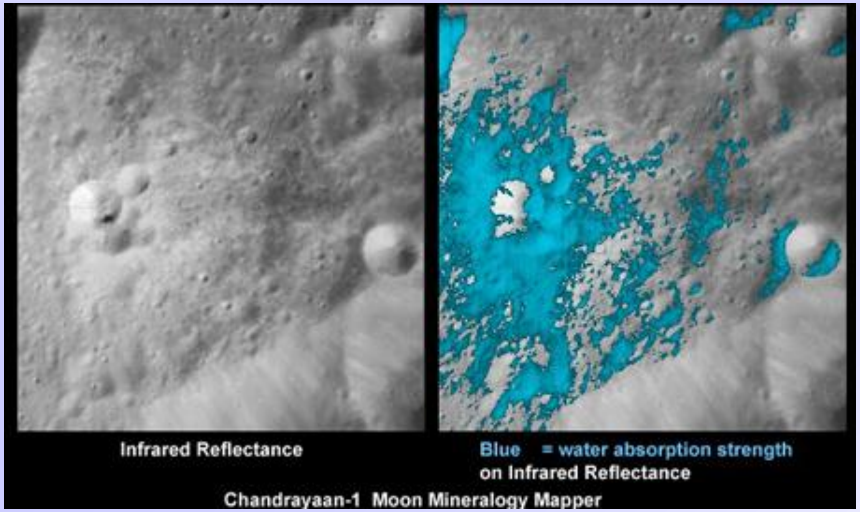
- Maximizing science and exploration,
- minimizing sample corruption,
- and lowering the costs of sample processing.

Examples of consortium studies on CSVC

CSVC Measurements & Science

Measurements of gas composition in the container head space with no terrestrial contamination.

- What is the composition and concentration of weakly bound volatiles in the lunar regolith?
- What is the nature of H species outside the polar regions of the Moon?
- How are volatile distributed, transported, and sequestered on airless bodies? This links to M3 and LADEE observations.



Measurements of volatiles in regolith with no terrestrial contamination or alteration.

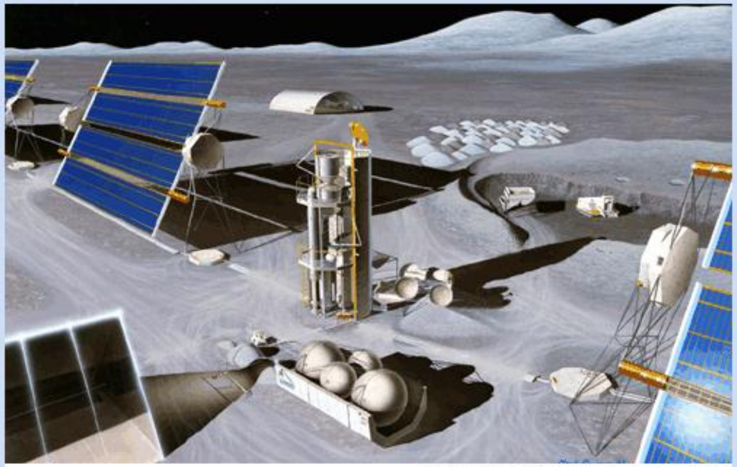
- How do volatiles from the lunar interior degas on the lunar surface (i.e. rusty rock 66095)?
- What is the nature of recent lunar degassing?

Examples of consortium studies on CSVC

CSVC human exploration studies

Measure volatiles in the most pristine lunar regolith samples from Apollo.

- What are potential lunar resources outside the lunar poles?
- How do we explore for lunar resources (i.e. link between ground truth and orbital data)?
- Are there health and safety issues tied to ISRU processing.

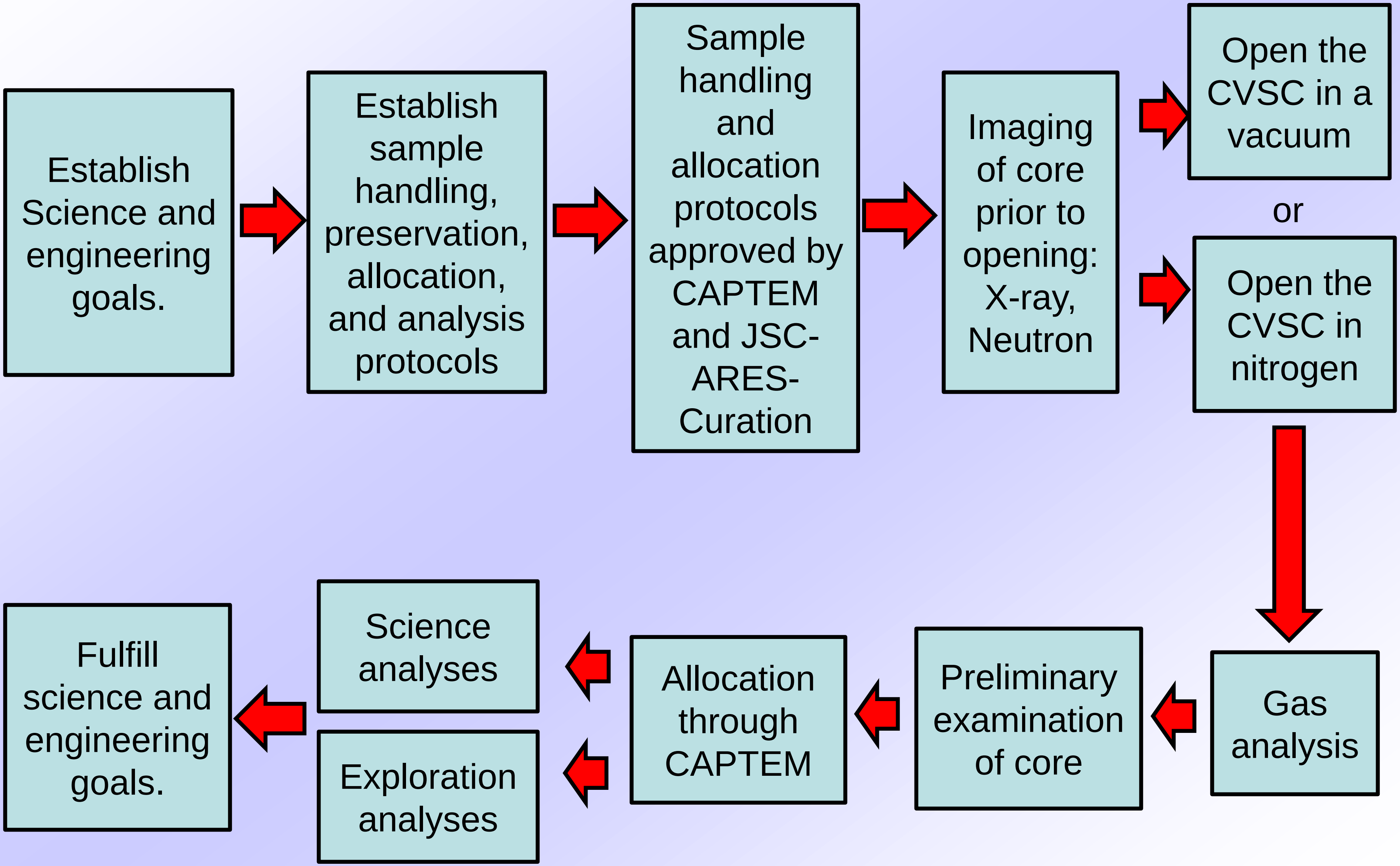


(NASA/Eagle Engineering artist Mark Dowman)

Comparison between CSVC samples and adjacent regolith collected via alternative methods.

- What should be the sampling protocol and sample container design for preserving sample volatiles during human activities on the Moon, NEAs, and Mars?

Establish goals and handling-analysis protocols



Summary

- The Apollo 16 and 17 **Core Sample Vacuum Containers** have the highest probability for lunar volatile preservation and will provide new perspectives that are relevant to recent observations and problems concerning volatile element behavior and reservoirs on the Moon.

- A CSVC study is equivalent to a lunar volatile sample return mission without the risk or cost of a mission.

- Such an imitative fulfills science goals identified in the planetary science decadal survey, has strong linkages to current and future missions, and fills strategic knowledge gaps for human exploration of the solar system.

- Cost involves planning, preparation, processing and curation of CSVC, PE and coordinated consortium analyses, and follow-on analyses.

- **Interested? Contact Chip Shearer: cshearer@unm.edu**